Volume 2 DECEMBER, 1923 Number 12

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 2 DECEMBER, 1923 Number 12

AMERICAN WELDING SOCIETY BULLETINS

If you do not have a complete set of the American Welding Society Bulletins you should order same at once. The price set on these bulletins for members are a figure that barely reimburses the Society for the cost of printing. They include:

Bulletin No. 1.—"Standards for Testing Welds." These standard tests comprise: (a) Shop Standard. A simple standard test for such purposes as checking the work of a welder, testing a new lot of welding wire, and testing the effect of some change in conditions. (b) Commercial Standard: For cases where more than one kind of test should be made but where the circumstances do not justify a complete investigation. (c) Research Standard: When a complete investigation of a weld is to be made for research or other purposes, all tests and examinations are made which will contribute any information in regard to the characteristics of the weld. Price per capy—members, 25 cents; non-members, 50 cents.

Bulletin No 2.—"Welding Wire Specifications and Folios." The specifications and folios are based on the data collected by the Welding Wire Specifications Committee as to the chemical analysis of welding wire used for both gas and electric welding in railroads, shipyards and other places and the service results obtained from the use of such wire. Price per copy—members, 25 cents; non-members, 50 cents.

Bulletin No. 3.—"Standards for Electric Arc Welding Apparatus." These rules provide standards for use in connection with specification, definition of terms, information relative to apparatus to be supplied by the manufacturer and by the prospective purchaser, respectively, and tests. Price per copy—members, 15 cents; non-members, 30 cents.

Bulletin No. 4.—"Training Course for Oxy-Acetylene Welders." A report prepared under the joint auspices of the Federal Board of Vocational Education, National Research Council and the American Welding Society. For the infromation of the person who is selecting the candidates the text includes a discussion of the qualifications which the candidate for training should possess. For the information of the instructor the text includes the fundamentals in gas welding, together with a number of type welding jobs arranged in the order of difficulty. These type welding jobs are divided into checking levels with the objective clearly indicated and the auxiliary information which should be given the student for each checking level. Per copy, 25 cents.

Bulletin No. 5.—"Welded Pressure Vessels." This report, which consists of 152 pages, contains the test data obtained as the result of the destructive tests of some 50 welded tanks, together with analysis of this data and recommendations to the Boiler Code Committee of the A. S. M. E. It contains many illustrations, charts and tables. Price to members, $1.50; to non-members, $5.00. Special rates on this bulletin may be obtained for quantity lots of ten and over.

BOUND VOLUME OF JOURNAL

In order to meet the demands of certain members the Society each year binds a few volumes of the Journal in attractive book-form. This year a suitable index will be included. In this way a permanent record will be provided for the best articles appearing on welding during the year. Copies are sold to members at $5.00. Orders should be placed at once for the 1923 volume as only a few will be put up. Attention is also called to the fact that there are five or six bound volumes of the 1922 edition still available.

Section Activities

Philadelphia

One of the most interesting and best attended meetings of the Philadelphia Section was held on Monday, November 19th, at the Engineers' Club, 1317 Spruce Street. A six-reel moving picture was shown on the "Manufacture of All-Steel Automobile Bodies," through the courtesy of the E. J. Budd Manufacturing Company. This picture was never shown in public before and was highly interesting to the welding industry, as it illustrated the use of electric arc, acetylene and spot welding.

Chicago

The second fall meeting of the Chicago Section was held Friday, November 2nd, at 8 P. M., in the rooms of the Western Society of Engineers, Monadnock Building. Mr. H. Ullmer presented papers on "Application of Oxy-Acetylene Welding and Cutting in the Mining Industry," and "Welding of Stellite." The latter paper gave in detail the methods found most successful in connection with the welding of stellite to machine steel shanks for use as a cutting tool. Both papers were discussed by those present.

The next meeting will be held on December 7th. The program will include a paper upon the "Electric Welding of Sheet Steel," by Mr. E. S. Hurd, of the Gibb Instrument Company, and also a paper on "Welding and Cutting in Connection with Car Repairs," by Mr. H. W. L. Porth, Master Car Builder, Swift Refrigerator Transportation Company.

Pittsburgh

The next meeting of the Pittsburgh Section will be held Friday evening, November 23rd, Mr. W. R. Hulbert, Sales Engineer, Metal and Thermit Corporation, will present a paper on "Alumino-Thermic Process." The paper deals with the application of the process to the reduction of metals and welding and will be illustrated with motion pictures and lantern slides.

New York

The first fall meeting of the New York Section, held on November 13th, was a huge success. About 120 people were in attendance. The unusual features of this meeting were the refreshments (cider and smokes), and the variety of papers presented.

Mr. C. J. Holslag presented a paper on "Proper Fields For the Use of Gas, Electric, Thermit and Resistance Welding." He was followed by Mr. W. H. Bleeker, of the Page Steel & Wire Company, who presented a moving picture on the "Manufacture of Commercially Pure Iron and Steel." The picture covered a trip to the openhearth, blooming mill, rolling mill and wire mill, covering all steps in the manufacture of wire, beginning with the ore.

The Section was honored by the presence of Major James Caldwell, who is known to most of the members of the American Welding Society through his visit to this country during the war, as an expert to advise with the Welding Committee of the Emergency Fleet Corporation in regard to the use of welding in ship construction. Mr. Caldwell presented a paper on "Fluxes and Their Functions in Electric Arc Welding."

Mr. Pliny P. Pies, Welding Engineer of the Lincoln Electric Company, described the arc welding of some fuel tanks in one of the city buildings. President T. F. Barton gave an interesting review of the happenings at the fall meeting of the Society in Pittsburgh. He spoke very encouragingly as to the prospects and future of the American Welding Society. The meeting was presided by Chairman E. H. Ewertz, of the Section, who is General Manager of the Bethlehem Shipbuilding Corporation.

The December meeting will be held on the 11th at which time Mr. C. F. Gailor will present a paper on "Arc Welding Copper to Steel." He will include a brief analysis of the development of arc welding copper bonds to steel rail which has resulted in a practical satisfactory weld between copper and steel which is of interest to welders, scientists and engineers and which opens up new possibilities. Lantern slides and exhibits will be shown.

The January meeting will be held on January 8th at the Jersey City plant of the Air Reduction Company where an inspection and demonstration of automatic welding and cutting machines has been arranged. At this meeting Mr. Hulbert, of the Metal and Thermit Corporation, will talk on "Thermit Welding," and show some motion pictures of thermit welds made on the steamship "Saratoga."

Northern New York

The November meeting of the Northern New York Section was held Thursday evening, November 8th, in the Civil Engineering Building of Union College. Mr. G. O. Carter, consulting Engineer, Linde Air Products Company, presented a paper on "Some Management Problems on Large Welding Jobs." Mr. Carter gave some interesting details in connection with the construction of a gas tank at Columbus, Ohio. The lower ring in this tank is 5/16" material and the bell is ⅛" material. The tank is 53 ft. in diameter and 27 feet high. In making welded joints between the steel sheets from ¼" to 3/16" per foot of joint was allowed for contraction. Mr. Carter stated that it was necessary to test the men out to determine their ability before assigning them work on this tank. He stressed the fact that workmanship on such jobs was of extreme importance and that he believed butt welding instead of lap welding should be used for this class of work. The following resolution was passed by the Section in memory of Dr. C. P. Steinmetz:

"Whereas, death has suddenly removed Dr. Charles Proteus Steinmetz, a scientist of international repute and a loyal co-worker of technical problems, and, whereas the Northern New York Section greatly feels its serious loss to itself and to the welding profession, be it

RESOLVED: First, that we, the members of the Northern New York Section, at our regular meeting, Thursday, November 8, 1923, hereby record our personal grief and deep regret at this great loss, not alone to us, but to the entire engineering and scientific world, and,

Second, that we express our sincere sympathy to the members of Dr. Steinmetz' family.

Third, that this resolution be incorporated into the minutes of this meeting and printed in the Journal of the American Welding Society."

Cleveland

The next meeting of the Cleveland Section will be held November 20th at the Engineering Rooms, Hotel Winton. The speakers will be Mr. R. E. Kinkead, of the Lincoln Electric Company, and A. E. Wetzell, of the Smith and Oby Company, of Cleveland. Mr. Kinkead will speak on the large welded pipe lines welded by the electric arc processes. Mr. Wetzell will present a paper on the "Advantages of Using Oxy-Acetylene Welding and Cutting in the Installation of Heating Systems in Large Buildings." At the October meeting of the Section Mr. S. B. Merry, of the Republic Steel Package Company of Richmond, presented a review of the steel package industry, including its early history, develpoment and use of welding and how a welded steel package is made to-day. The December meeting will be held on the 16th at which time Mr. R. L. Hemingway, of the Industrial Accident Commission, will discuss the report of the American Bureau of Welding on the "Welding of Unfired Pressure Vessels."

Boston

The November meeting of the Boston Section was held on November 9th at the Boston City Club. Professor C. A. Adams, Director of the American Bureau of Welding and Past President of the American Welding Society, reviewed the benefits to industry of the activities of the American Bureau of Welding, and he gave an account of the results already accomplished, mentioning particularly the advantage of scientific research in the development of industrial applications of welding.

EMBLEM

All members of the Society are privileged to wear the Society emblem. Emblems may be obtained in two styles from the Secretary's office.

Price, gold-filled, 75c., 14-K. gold, $5.00.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the Bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

POSITION VACANT

V-14. Have opening in the Welding Division, Practice Department, requiring the services of a thoroughly experienced welder capable of supervising oxy-acetylene, electric and thermit welding in all its branches. Applicant must be highly efficient on inspecting jobs and be able to estimate time, material and method required to complete same.

V-15. Salesman. Need first-class salesman for New York territory to sell oxy-acetylene welding and cutting equipment. Must be an order getter.

SERVICES AVAILABLE

A-20. First-class welder desires position. An expert welder who can supervise, demonstrate, also act as consulting welding engineer. Have eight years experience on ship repair and ship cnostruction, in locomotive plants and engineering work of all kinds in welding field. Can furnish excellent references. Willing to travel anywhere and accept position either as welder or superintendent.

A-21. First-class electric welder desires position. Thoroughly familiar with oxy-acetylene welding and cutting. Want position where a steady, devoted ambitious man will receive consideration. Prefers to be located in Washington, Pennsylvania or Eastern Ohio. However, will consider other places. Have had three years' experience in charge of welding shop.

1923 Bound Volume of Journal

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ARC WELDED RAIL BONDS*

C. F. GAILOR †

History

The development in the art of electric arc welding bonds to steel rails has been both rapid and phenomenal and when compared to the progress made in other fields of electric arc welding it can be fairly stated that more actual progress has been made in this particular field than in other lines of electric arc welding. This is particularly true in the case where all-copper bonds are welded to rails with copper electrodes.

The exceptional merit of copper as a conductor was never overlooked for a moment by the engineers and inventors of this particular method of bonding, although considerable time was spent in studying and endeavoring to secure satisfactory results with other metals. It was very definitely and clearly shown in the beginning that pure copper, both for the manufacture and welding, produced a bond possessing highly essential merits and very much lower in electrical resistance than any other substitute or combination of metals known to the industry.

It is comparatively recent, probably within the past ten years, that the practice of electrically arc welding bonds to rails was accomplished in a reliable and satisfactory manner. The first attempt to arc weld copper bonds to rails was made by using, both for the bonds and the filler needed, pieces of old trolley wire or similar articles from the pile of scrap copper which were welded with the carbon arc method. The addition of sufficient scrap copper to produce the desired mass of copper around the end of the bond to form the terminal was accomplished in the usual manner. It was considered necessary at that time to secure deep penetration with the arc into the rail steel to produce a desirable weld. This practice caused unnecessary gouging of the rails, burning of the steel and usually resulted in an ugly-looking weld of questionable character. Fortunately a careful study of the factors involved quickly demonstrated the fallacy of this practice and resulted in the development of the welding process which eliminates this feature, as will be shown later.

Character of Bonds

There were many attempts made to manufacture a rail bond having a suitable head or terminal which could be satisfactorily welded to the rail without the use or assistance of a mold. This was found very difficult if not impossible, due to the fact that the action of the copper metal, when in a fluid state under the influence of the arc, made it very difficult to secure a weld or amalgamation between the steel and copper metal.

The copper in a small mass, or in a volume such as would be

* Paper to be presented before Dec. 1923 meeting, New York Section.
† Consulting Engineer, Rail Welding & Bonding Co.

more desirable in this practice of welding, would usually chill without producing a weld. The use of molds made it possible to use sufficient copper around the bond to produce a reliable weld and at the same time form a head or terminal on the bond in the most suitable shape, size and location.

Use of Molds

The problem of confining the weld metal itself, the area of contact and the necessity for producing a weld and bond terminal of a suitable character, as well as a design to conform to the best practice in bond manufacture, prompted the use of a mold to accomplish the best results. It was quickly found that a carbon mold seemed to meet the requirements better than any other material. The result was that a carbon mold in one form or another has been in use since the very beginning of this method of bonding.

Fig. 1
Photo-micrograph showing actual weld between copper bond and steel rail, also the homogeneous structure of the bond.

Carbon as a refractory will withstand the action of the arc and erosive action of the metal when boiling in the mold, and will not chill the metal as rapidly as most other materials. It was also found difficult to produce a satisfactory weld in the remote corners of the mold, especially on the smaller sizes of bonds where the metal and the angle of contact was limited. Here again the carbon proved its superiority over the other materials. In some cases where materials were used for experimental purposes it was found very difficult to force the copper metal into the corners of the mold, as the material had sufficient chilling and repulsive action to hold the copper back for an appreciable distance from the corners. This information, however, was decidedly useful, because it proved con-

clusively that acute angles in the mold and limited sections of copper welding should be avoided.

The carbon molds are designed to produce a terminal and welded contact to the rail equal to at least four times the cross section of the copper metal in the bond itself. This allows practically a

Fig. 2—Mold and mold holders during process of welding, carbon arc method being employed in upper three figures. Lower figure shows molds for welding bonds to base of rail by metallic arc process.

factor of safety of four, so that it is virtually impossible for an operator to apply a bond which in the finished product would not test 100% efficient. A larger contact terminal could not be justified.

During the development of the process and particularly the study of the carbon mold situation it was found that the use of a combination of copper, steel and carbon for the mold was most desir-

able. This construction was found quite necessary when it developed that the mass of carbon needed around and under the base of the head of the bond was considerably more than the space available between the finished bond terminal and the top of many of the heavy section joint plates now in use. The combination of these materials enables the bond to be applied at a point on the head of the rail very much lower than would be possible if an all-carbon mold were used.

The life of such carbon molds, of course, depends largley on the welder, the care and attention received, but as a rule it is found

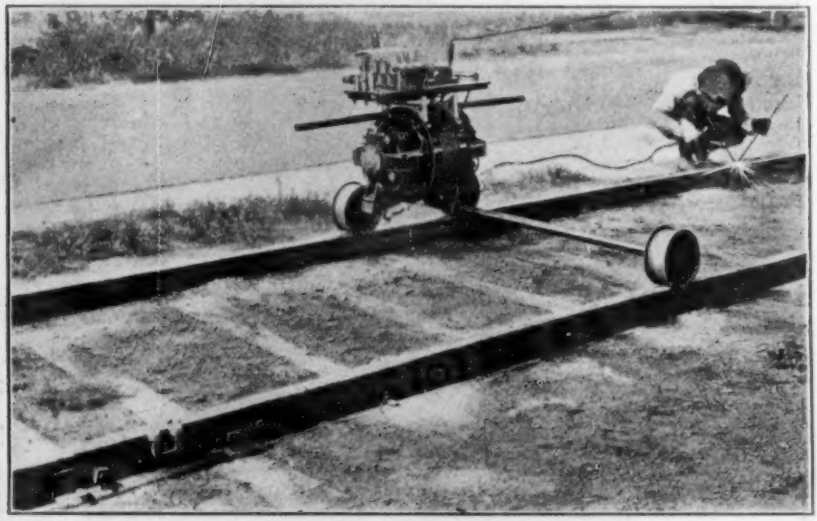

Fig. 3—Photograh showing a common type of welding outfit for carbon arc method of bonding.

that a set of carbons will weld 40 to 50 bonds and in many cases this number is nearly doubled, so that the use of molds, particularly when the speed of the operation is considered, and the much larger welded contact to the rail is obtained than would otherwise be the case, are fully justified even though the cost of such accessories is a factor in the total cost of the operation.

Welding Processes

The investigation and research work covering the development of bond welding resulted in the development and perfection of two diffrent methods of welding in which practically the same results were secured.

Carbon Arc Welding

One method covers the use of the carbon arc process of welding which includes the use of reversed polarity, that is, the carbon electrode is negative, and in a general way represents the original method of bonding. However, instead of using scrap copper for a

filler or electrode, the use of a copper alloy welding rod is employed as a result of this investigation. The copper alloy rod, although practically pure copper, contains a combination of metals sufficient in quantity to act as a strong deoxidizer for both steel and copper and under the influence of the arc will thoroughly cleanse the steel surfaces thus assuring the pure copper coming in contact with the steel in the rail under the most favorable and practical conditions. This result in a homogeneous amalgamation of the two metals in a very desirable manner. The action of the copper alloy rod obviates the possibility of burning or unnecessary gouging or penerating the rail steel. In fact, the best bonds are produced where this feature is carefully avoided and where the arc is drawn along the surface of the rail steel close enough to secure the desired weld but still far enough away to avoid any direct penetration. The

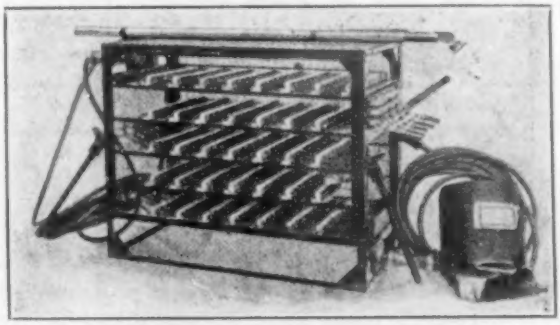

Fig 4—The usual type of resistance welder used in metallic arc method of bond welding.

action of the copper metal in the mold under the influence of the arc is very similar to that of copper when handled in a crucible which easily brings all the foreign substances and slag to the top, thus leaving the pure copper forming the bond terminal welded to the rail in a very efficient manner.

The welding operation, when this particular method is employed, consumes practically the same amount of time and otherwise compares closely with the metallic method of welding. It appears from considerable practical observations that this particular method is not only desirable but recommended in all cases where dynamotors and similar low voltage generating units supply the necessary electric current. It is found on regular bonding operations that a bond of the ordinary standard size and type can be welded in approximately two minutes' time. This includes the entire operation. There are many instances where conditions are sufficiently favorable to allow operators to install bonds in half the time but as a practical proposition it is found that the installation of bonds at a rate of two minutes per bond is satisfactory. One of the principal reasons for the operation requiring such a minimum amount of time is the fact that the copper melts and flows very much faster than other metals used for this purpose.

In bond welding it has been found very essential that sufficient current be available to keep the copper metal flowing uniformly and the metal in the mold always in a fluid state. Otherwise, the metal will chill and the cleansing and boiling action of the metal, which is highly necessary, is prevented. Practice has shown that it requires at least 200 amperes to successfully weld bonds with this method.

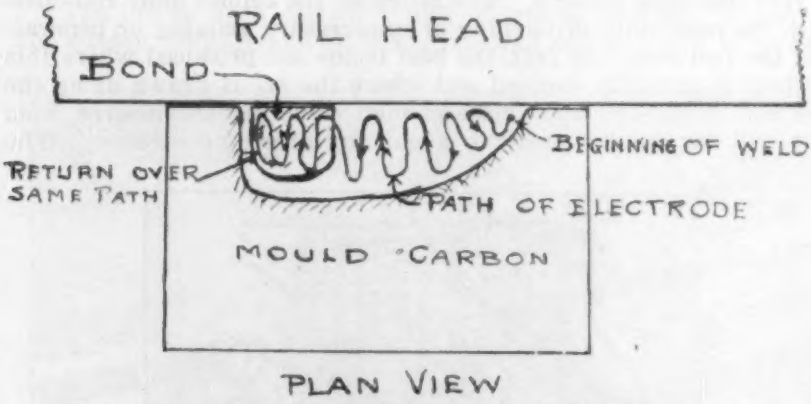

Fig. 5—Sketch showing path of metallic electrode in this type of bond welding.

Metallic Arc Welding

The second method of bond welding, and which in reality is the result of the exhaustive investigation and research work started about three years ago, resembles considerably the ordinary metallic method of welding but in reality it is distinctly different, as the welding metal must all be kept in a molten state and the length of arc changed from time to time to produce a good weld.

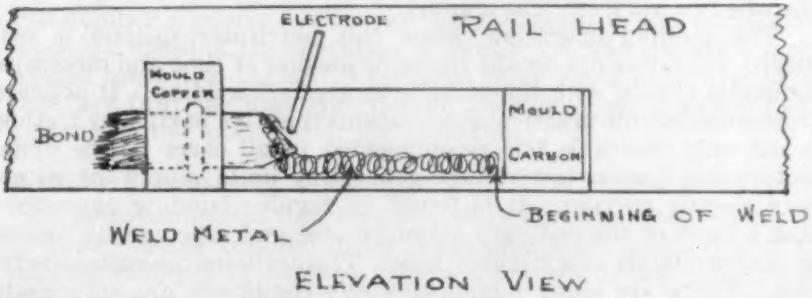

Fig. 6—Sketch showing method of welding Webber type bonds

In practice the same molds and accessories are employed. The current is usually supplied by a light-weight portable resistance welder having sufficient capacity and regulation to meet the requirements. The usual practice being to use a 3/16″ diameter copper alloy rod as a positive electrode which requires approximately

225 amperes to weld successfully and keep the metal in the mold hot enough to produce the important action heretofore explained.

The following extract from an instruction sheet on this particular method of welding describes very clearly the actual method employed in handling the electrode when making a weld of this character.

Process in Applying Bonds to the Head of the Rail

Set the dynamotor or resistance welder to produce at least 225 amperes.

Strike the arc by touching the electrode to the top edge of the carbon forming the mold, at the end remote from where the bond head projects into the mold. Holding the arc about $\frac{1}{4}$" to $\frac{3}{8}$" long allows enough molten copper to deposit and cover the bottom of the mold, making sure that the deposited copper is welded to the

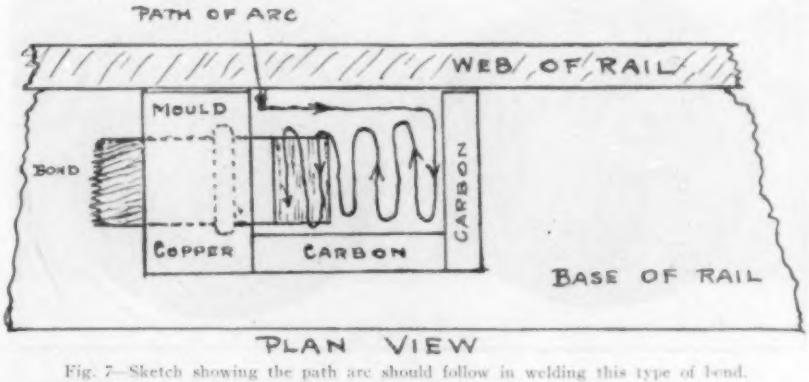

Fig. 7—Sketch showing the path arc should follow in welding this type of bond.

rail. A globule of molten copper will start to form in the end of the mold. The arc should be kept at the front edge of the globule, allowing it to enlarge until the entire bottom of the mold is covered. When the arc reaches the head of the bond it should be shortened to not over $\frac{1}{8}$". The bond head will start to melt, the molten metal being swept back to the molten copper in the bottom of the mold. Proceed slowly over the bond head so that the strands will be melted down and all the strands caught.

After the bond head is melted down, the arc may be lengthened to $\frac{3}{8}$" to $\frac{1}{2}$" and played back and forth, and in and out from the rail over the entire head. This keep all the copper molten and insures that the head is well filled out in the back and properly welded to the rail.

Procedure in Applying Webber Type Bonds

Set the welder so that 225 to 250 amperes is obtained. Strike the arc by touching the carbon of the mold at the end remote from the bond head and hold $\frac{1}{4}$" to $\frac{3}{8}$" arc. Play the arc in and out as described previously until the bottom of the mold is covered. When

the bond head is reached, shorten the arc to 1/8" and melt down at least the lower half of the head before going back to fill in the head. Be sure to allow the arc to melt back the lower edge of the bond head before it is covered with deposited metal.

Fill in the mold, using a 3/8" to 1/2" arc,, which is played back and forth and in and out from the rail, as heretofore outlined. Each time you approach the bond head, shorten the arc to approximately 1/8" to make sure that all the strands are melted down.

Procedure in Applying Base Bonds

Strike the arc by touching the carbon in the inside corner of the mold back of the bond head. Allow the arc to advance along the back edge of the mold and down across the outer end. Now play

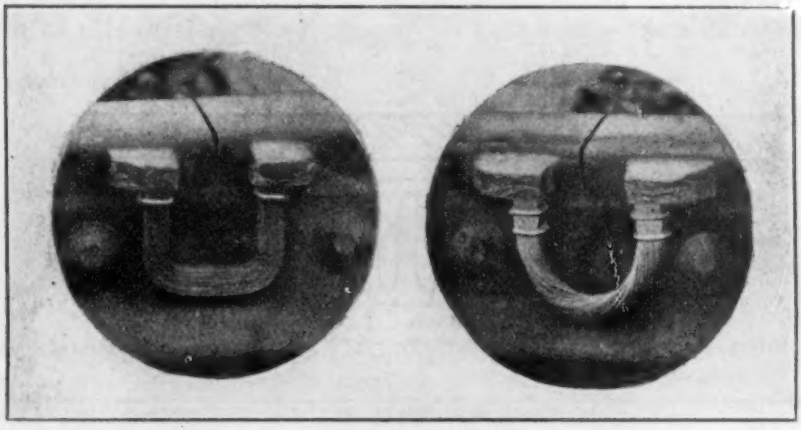

Fig. 8—Photograph showing usual laminated and single cable type bond welded to rail heads.

the arc back and forth across the base of the rail until the head of the bond is reached. Until the bond head is reached, a long arc, 3/8" to 1/2" in length, should be held. Upon reaching the head, be sure that the lower strands are melted down before they are covered with deposited metal.

As soon as the arc touches the bond head, shorten the arc to 1/8". The short arc is always necessary to properly melt down the bond head. Before withdrawing the arc from the bond head, the lower half at least should be melted down. Fill in the mold the same as described under Webber bonds, using 3/8" to 1/2" arc, which is played back and forth and in and out from the rail.

Mechanical Tests

During the development of the process of bonding and the various types of bonds required to meet the conditions presented by the great numbers of different rail sections and track conditions, it was found quite necessary to make mechanical tests in order to definitely prove the principles involved and also to give some practical idea of the comparative life of the various bonds.

The mechanical method of testing bonds proved its importance throughout the study of the subject of the welding heat at the head of the bond where some engineers seem to be skeptical regarding the so-called over-heating or weakening of the strands or laminations where they join the head or terminal. The mechanical tests have clearly proved that such bonds have a very much longer life when applied in this manner. In a number of test cases the weld bond possessed double the life of the same bond when applied mechanically.

The machine used for mechanically testing bonds consists of a steel framework carrying two upright standards which were

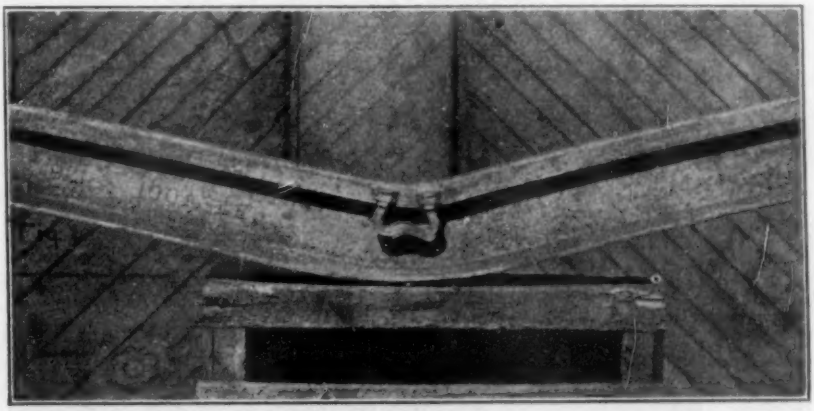

Fig. 9—Photograph showing condition of high carbon rails which were bonded and then subjected to severe drop tests.

mounted on eccentrics in such a manner as to give a maximum movement of 13/32″ between the two members. The bonds were welded to pieces of steel and inserted between the two upright members and the machine operated continuously until failure occurred. This movment, being far in excess of that resulting from actual practice, was adopted in order to speed up the operation. A summary of several of such tests show the following results:

The seven-inch 4/0 laminated U-type bond failed at approximately 5,100,000 vibrations.

The nine-inch 4/0 Weber U-type bond failed at approximately 2,403,000 vibrations.

The eight-inch single cable U-shap bond failed at approximately 1,830,000 vibrations.

The eight-inch double cable U-shape bond failed at approximately 1,050,000 vibrations.

Considerable thought was given to the strength of the bond heads when subjected to shearing stresses such as are apt to be imposed upon bonds welded to the head of rails. Several methods of testing this feature of the welded terminals were tried with varying results, but the most valuable of those tried was a simple shear

test to show the relative strength of the weld and the copper forming the bond terminal. This test clearly indicates the exceptional merits of the weld and adjacent metal, as the load required to shear the bond terminals ran well over 30,000 lbs.

The use of the sleeve or petticoat at the junction of the bond head and bond itself was shown to be very valuable as a result of these tests. This petticoat and the head on the bond itself holds the strands and laminations in one solid mass which prevents the welding heat from attacking or over-heating any individual strands and at the same time throws the bending action that would otherwise concentrate close to the bond head, back into the flexible portion of the bond where it is most readily dissipated. This particular feature was found to add practically 25% to the life of the bonds.

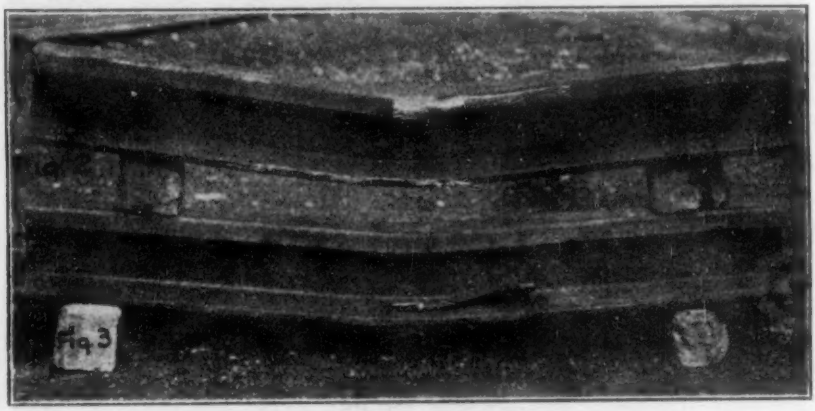

Fig. 10—Photograph showing condition of high carbon rails which were bonded and then subjected to severe drop tests.

Electrical Tests

The question of securing reliable resistance tests of welded bonds has not been an easy matter to solve, as it was found, after a preliminary investigation, that there are very few if any instruments available which could accurately and reliably measure the resistance in the contact between the welded copper bond head and the rail steel. The following is a brief summary of resistance tests which include one-inch of steel at each bond head and the bond itself. No fish plates or mechanical connections were used, so that these results show the actual resistance of the bonds enumerated.

	Ohms Resistance
Six-inch 4/0 laminated U-shaped bond	0.0000389
Seven-inch 4/0 laminated U-shaped bond	0.0000493
Eight-inch Webber type bond	0.0000454
Eight-inch single cable U-shaped bond	0.0000516
Eight-inch multiple cable U-shaped bond	0.0000484
Eight-inch 400,000 c.m. single cable U-shaped	0.0000260

These results have been checked from time to time and a recent

report of a preliminary test conducted by one of the most reliable testing laboratories in this country checked these values indicating that these figures, while exceptionally low for resistance of welded bonds, are correct.

Miscellaneous Tests

The most careful consideration was given to the study and examination of the rail steel at and adjacent to the point of weld. It was found that the idea of securing even the usual penetration when making a bond weld was not only decidedly wrong from a bonding point of view, but created a condition that proved disastrous when mechanical tests were conducted to determine the effect on the rails. The cutting or arc penetration of the rail section produced an objectionable condition at this point which would be liable to cause failure in the rail section.

The improvement in the process of welding, as outlined herein, quickly eliminated this feature, by making it both unnecessary and improper to penetrate the steel with the arc or electrode, but to carry the tests to a definite conclusion it was necessary to make many tests to establish this fact.

Among many other tests, which were conducted to prove that the welding of copper bonds to steel rails with these processes of welding did not weaken or materially effect the structure, were severe drop tests made on extra high carbon tee rails by dropping the 2,000-lb. tup so as to strike the rail at the point of weld. No failures or indications of any objectionable character were in evidence at the conclusion of these tests. The rails were removed from the testing apparatus because of the excessive vertical deflection which caused the rail to rest on the bed of the machine.

Aside from the area heated during the welding, which was in no way found objectionable, there was no evidence of any change in the structure of the steel or the rail section itself. A most thorough study of all the factors were conducted to definitely establish this fact and the results were most gratifying, as a glance at the drop tests and the photo-micrographs will show. There is a large volume of data available on this particular subject which is very interesting and instructive but far too voluminous to be included in this article.

The exhaustive studies and research work which necessitated not only electrical and mechanical tests but a very thorough metallurgical and micro-photographic analysis as well, have revealed some very beneficial information which is being further investigated, and as soon as sufficient conclusions can be drawn, to make use of the practical application of this information, additional data can be expected. The additional research work in progress will probably have very little bearing on the results or character of the present processes of welding or the bonds in use, but it is expected that it will be of exceptional interest to engineers and specialists who are interested in the technical problems involved in such a thorough investigation.

WELDED RAIL BONDS

H. H. Febrey †

The method of attachment of copper bonds to steel rails is a problem which has engaged the attention of engineers since rail bonds were first required. Various mechanical means of attaching bonds have been developed, some remaining in extensive use today, others have passed into the discard. Whether or not mechanical types of bonds will reach complete obsolescence is a question. Some of them possess inherent advantages which it will always be difficult to overcome with welded bonds.

The soldered bond came and went and the brazed bond followed in logical sequence. By brazed bond I mean one which is applied with brass instead of soft solder, in a manner analogous to soldering.

As soon as arc and gas flame welding were commercialized effort was made to apply rail bonds by welding. For several years development work in this direction has been going on. The changes and improvements in the art have been rather rapid and in the arc welding field the designs of bonds have been changed frequently within the last few years. I think it safe to say that all welded bonds are now highly developed, but they have not reached perfection.

As it will be necessary to describe the makeup of various bonds I will explain the terms used for the parts composing a rail bond. The terminals are the parts which are fastened to the rail. The conductor is the copper cable or wire connecting the terminals.

Flame Weld Bonds

As bonding by gas flame welding is comparatively simple I will cover that first. The early flame weld bonds had drop forged copper terminals welded to the bond conductor. The terminals had a welding surface considerably larger than the cross section of the bond in order to provide adequate mechanical strength. The first bonds were attached with copper as the welding metal. As the copper terminal was expensive, a steel terminal was devised which was fastened mechanically to the copper bond conductor, the end of which extended into an opening in the welding surface.

It was soon found that copper as a welding rod produced poor results. The copper oxidized excessively and gave the attaching metal low mechanical strength and low electrical conductivity. A deoxidizer in one form or another was required and it was found that this could be incorporated in the welding rod with facility. Copper alloyed with 1.00% to 4.00% tin and .01% to .04% phosphorous gives excellent results. A dense and homogeneous metal can be deposited, the metal flows evenly and is easily worked in the

† Engineer, American Steel & Wire Co.

flame. This alloy has a strong affinity for steel and "takes" as readily as solder when the steel is at proper temperature.

The steel terminal flame weld bond is used very widely. However, there are some who prefer the more expensive copper terminal which bonds are slightly lower in resistance.

The advantages of the flame weld process are mainly the obvious ones; adaptability to new construction, where there is no electric power, and to high voltage trolley systems. There is also the advantage of simplicity of the welding process compared with the present stage of arc welding development. The method is rapid, the form of bond cheap, clamps for holding the bond in position on

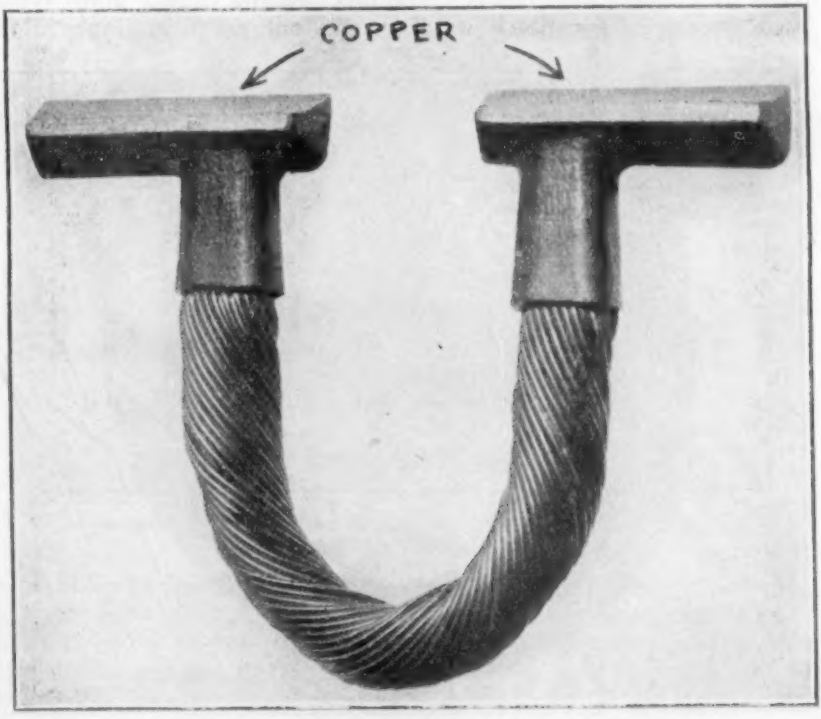

FIG. 1—COPPER TERMINAL FLAME WELD BOND.

the rail are of little importance, and the bonds can be applied to any part of the rail with equal facility and without the aid of molds.

There is the disadvantage of exchange of tanks and the handling of them on the job. Also the gas is expensive compared with trolley power.

There are a number of 600-volt trolley roads that use flame weld bonds in preference to arc weld types, mainly because they are able to obtain better results with the labor at their command.

Arc Weld Bonds

I believe it will be interesting to follow the actual commercial

development of arc weld bonds in sequence, as this will explain why the various kinds have been used.

Arc weld bonds have not been as easily developed as flame weld bonds. I will discuss them in the order of their commercialization. The first bond for arc welding employed a carbon electrode and an all-copper bond. A carbon mold was required in order to retain the attaching metal which was puddled by the carbon arc. This general type of arc weld bond is still active commercially. At first the attaching metal was pure copper and scrap copper wire was relied upon largely. Trouble with respect to the rapid oxidation of the molten copper was experienced, the same as was the case with flame weld bonds. The flux bearing copper alloy, which was developed for flame welding, did not seem to improve the

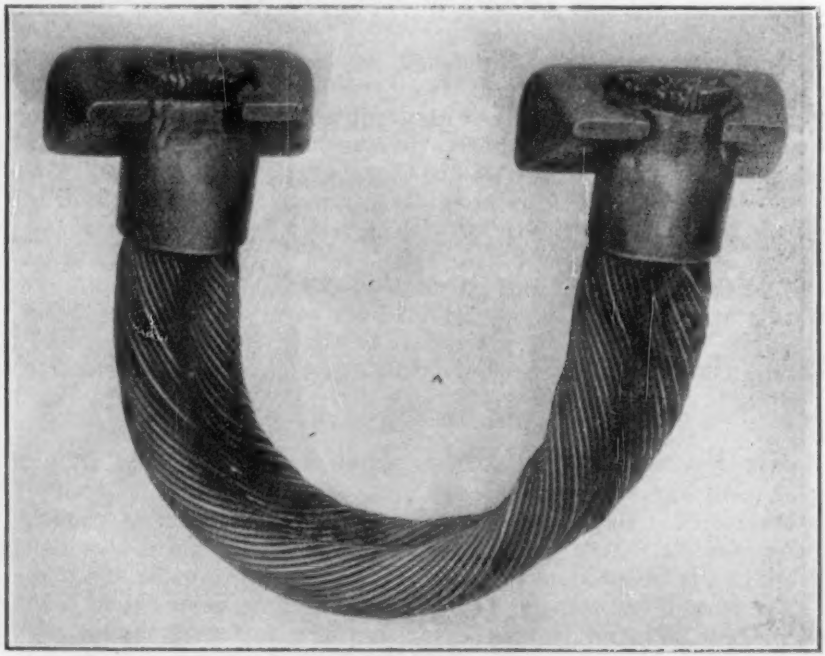

FIG. 2—STEEL TERMINAL FLAME WELD BOND

character of the attaching metal when fused in the carbon arc. Recently a copper alloy has been developed which is self-fluxing when fused in the arc, and this has greatly improved the application of copper terminal bonds with the carbon arc.

The bonds for carbon arc welding require negative polarity of the electrode, consequently a dynamotor or motor-generator set must be used because of the positive trolley. The track is normally negative. A portable rotary type welder for the usual 500/650 volt d. c. system is heavy and expensive. It has, however, the decided advantage of low open circuit voltage at the generator. The ballast resistance type welder is not suitable for carbon arc welding.

One of the advantages of the carbon arc method of attaching bonds is the fact that the bond conductor can be welded directly to the attaching metal, thus making a simple type of arc weld where the parts to be joined are each welded to the attaching metal. The form of bond for carbon arc welding is simple, requiring some form of mechanically attached retaining member on the ends of the bond conductors to hold them together and to hold them conveniently in a mold designed for the purpose.

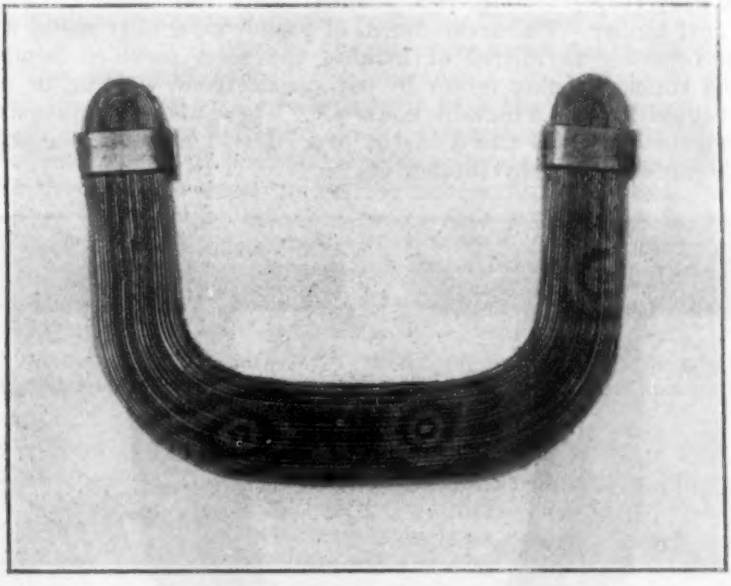

FIG. 3—BOND FOR CARBON ARC WELDING HAVING A STEEL ENCASED TERMINAL.

Naturally it was desirable to apply bonds with the metallic arc, but attempts to do this with a copper electrode and all-copper bond did not prove successful The copper oxidized and would neither fuse to the rail nor to the bond.

It was logical to assume that if a steel plate could be attached to the copper bond, a steel electrode could be used and a bond obtained for metallic arc welding. Such a bond would permit of the use of any type of welding machine, resistance or rotary and positive or negative electrode polarity.

The first bonds for metallic arc welding had a steel plate brazed with brass, to the copper bond. The steel plate was about 1/16″ thick. Adjacent to this was a layer of brass and then the copper. Obviously it was difficult to weld the steel plate to the rail without melting the brass by the welding heat. Obviously a bond of this character had to have an inseparable union between the copper and the steel in order to be successfully welded with a steel electrode.

Consequently the next development was a bond in which the steel jacket was directly welded to the copper in the factory. These

bonds are in extensive use today. In the manufacture a hollow steel box is first formed and the end of the copper cable is inserted part-way into the hollow box. With the aid of a carbon arc the hollow steel box is filled with copper, thus uniting the cable and the steel jacket in a homogeneous mass. In the earlier bonds of this type the steel boxes were filled with pure copper which was oxidized by fusion in the carbon arc. In order to refine this metal the terminals were re-heated to a rather high temperature and then drop-forged into finished shapes. This heat treatment refined the cast copper. The development of copper alloy filler metal which is self-fluxing permitted of making the steel jacketed bonds by filling the steel boxes either by carbon electrode welding or using the copper alloy as a metallic electrode. These alloys produce dense, homogeneous metal fused in the arc. I will mention the copper alloy more specifically further on.

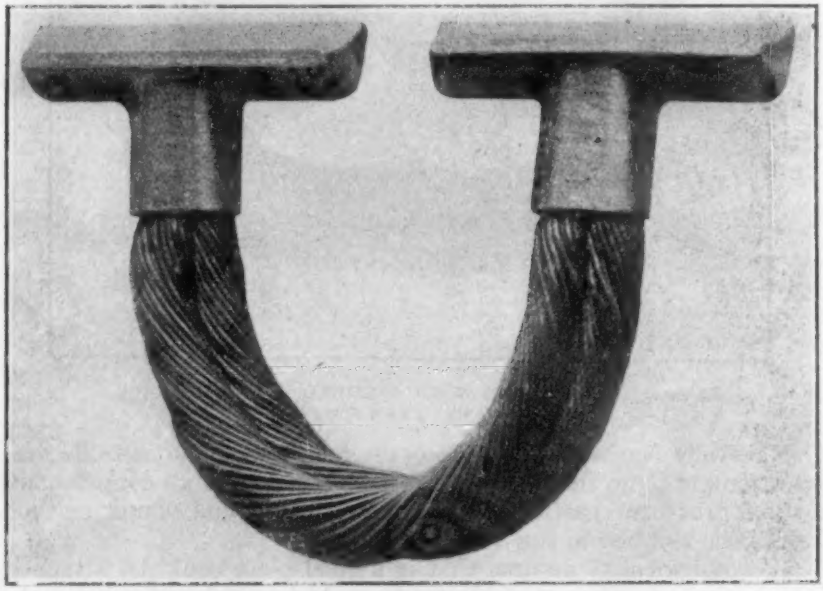

FIG. 4—BOND FOR STEEL ELECTRODE WELDING.

The advantages of the steel jacketed arc weld bonds are that the terminals can be shaped in any convenient manner in the factory to suit the various positions in which they are to be attached to the rail. From the railroad man's standpoint the bonds have a decided advantage in simplicity of weld and lack of special appurtenances requisite in applying the bonds. The steel weld is simply another steel weld, the same as the men are making on rail joints and rail repairs, and the only accessory is something in the way of a clamp to hold the bond in position while it is being welded. Often no clamps are used. The bonds can be attached with equal facility to any portion of the rail without the aid of molds.

The chief objection to these bonds is the indirect method of attaching a copper bond to a steel rail. There is a weld between the copper cable and the terminal, and a weld between the steel jacket and the rail, which has to be made in the field. A relatively large area of weld is necessary in order to compensate for the difference in conductivity between the steel and the copper.

An important development in the matter of arc welding rail bonds is the copper alloy electrode. One of these alloys is copper containing approximately 0.25% silicon as a reducing agent. When fusing this alloy in the carbon arc or fusing the alloy as an electrode, the metal flows easily and the reducing agent floats out the oxide on the steel surface and whatever oxide tends to form on the copper surface. It is not necessary to take the ordinary oxide off the rail. All that is necessary to do is to remove the dirt with a wire brush. At the present stage of development it is necessary to puddle this alloy in order to get the proper fluxing action. It therefore works best with a carbon arc using a mold to retain the molten metal, or using a high arc current when used as a metallic electrode and puddling the metal in a mold. If an attempt is made to use the alloy electrode similarly to a steel electrode and hold the arc current down to a point where the metal will not run away, it does not seem to have time to flux out the oxides and effect good fusion on the surfaces to be joined nor homogeneity of the deposited metal.

As to the effect of welding on the rails, laboratory tests have been contradictory and experiences in practice are overwhelmingly one-sided. The number of actual rail failures which have been attributed to bond welding are insignificant as compared with the millions of welds which have been made and are giving no trouble.

Opinion varies considerably as to what part of a rail is affected most. Many are skeptical about welding to the rail web, and some likewise regarding the rail base or flange. The least objection seems to be to welding on the side of the rail head, near the end of the rail.

Two interesting installations of arc welding bonds applied with steel electrode were made on electrified steam railroads two and a half years ago. These installations were made for the express purpose of testing the effect of the welding on the rails under actual service conditions. The conditions prevailing on one road are high speed, frequent trains and heavy equipment, mostly all Pullman cars. On the other road the traffic is equally heavy but the speed is slow. The weight of equipment is very heavy, mostly coal cars. Welds were made on the head, web and base of the rail and the rails were 130 lbs. per yard with continuous type joints. The rails bonded have been in service since early 1921 and frequent inspections have not revealed any faults whatever.

On another electrified steam road where the traffic is heavy and frequent, but equipment lighter (mostly multiple-unit trains),

similar bonds were installed about the same time, both on the head and the web of old 100-lb. rails. There was a failure of one rail end at the joint where the bond was welded to the web of the rail. Inspection of the fracture indicated to me that there was a flaw extending the full height of the web where the failure occurred. However, this one failure has made the engineers of that road skeptical of welding to the rail web. It is quite probable that this rail would have broken had a hole for a mechanical type bond been drilled where the weld was made.

The welding of rail bonds presents an unusual problem to the welding engineer. There is a repetition of a large number of small welds to be made under widely varying conditions. The apparatus for applying the bonds must be adapted to the conditions as found and readily portable. The operators assigned to this work are often hastily trained and of mediocre ability. It is the exception to have what the welding engineer would consider a trained welder available for rail bonding. Consequently, the development has to be along lines which embody simplicity, so that the average and below average workman can make satisfactory welds. It is necessary to make rail bonds as nearly fool-proof as possible in the matter of their application.

Obviously it is not easy to obtain perfect welds in applying rail bonds with a ballast resistance type of welder. The open circuit voltage is very high, producing an injuriously high arc voltage, unless the operator is very careful, and the electrode is positive. The resistance type welder, however, has so many advantages which appeal to the railroad man that its use is extensive and seems to be growing. This is particularly true in coal mines where rail bonds are required extensively and the arc weld types of bonds are now used in large majority over mechanical types. The resistance welder is cheap in first cost, very light in weight, of small dimensions and requires practically no maintenance. It is only extreme carelessness which causes damage to this type of welder.

Unlike most welding problems, in the case of rail bonding the work has to be adapted in large measure to the apparatus for installation. Fundamentally, copper and steel must be welded together somewhere in the process, whether at the factory or under the adverse conditions found along the tracks. There appears to be an equal chance of development of copper terminal bonds welded to the rail with copper or other alloy, and steel encased terminal bonds which are applied with steel electrodes. I believe that much depends upon the development of electrodes for both steel and copper welding. It is desirable from the users' standpoint to have a bond which does not require a separate mold to be used with the bonds. If an electrode can be developed which will work satisfactorily at a high arc voltage, positive electrode polarity, and not requiring the use of a separate mold, it will be a great boon to the rail bonding art.

A RESUME OF RESISTANCE WELDING DEVELOPMENT FOR THE PRESENT YEAR*

H. A. WOOFER †

The branch of electric welding known as Resistance Welding has not experienced any basic change, patent, or discovery during the last year, although experiments and research have been carried on constantly. These have, however, increased the technical and special knowledge of the art in practically all directions, but especially in the spot and butt welding fields.

SPOT WELDING

Taking up spot welding first, the present tendency is towards power-driven, automatic machines, especially for heavy work. The reason for this is apparent. Heavy work requires heavy pressure ranging from 2,000 to 10,000 pounds per square inch to complete the weld. If this pressure must be delivered by the operator himself by means of a foot lever, he will soon grow tired; neither can he be expected to exert exactly the same pressure on each successive weld. The power-driven, automatic spot welder, however, does not grow weary, and when once adjusted for pressure, current and cutout, operates continuously in exactly the same manner, making all welds identical, and leaving the operator free to handle the work only.

Ten of these large power-driven, automatic spot welders are now in operation in different classes of work. It might be interesting to mention their uses. Two are used in making cutter bars for harvesters and mowing machines, two in making special machinery, two are making automobile disc wheels, one is making steel burglarproof safes, on is making paper mill machinery, one is making gear covers for railway motors, and one is used for experimental purposes in a laboratory. They are rated at 100 K. V. A., 75 K. W., and are capable of welding a maximum thickness of $\frac{3}{4}$" of stock. They are equipped with both a time cam cutout and a movement or tong type cutout. If, for any reason, the movement of the upper die is not sufficient to cut off the current before the pressure is released, the timing cam cuts it off automatically, thus prventing burning of the dies or work.

Another step in advance for the past year is the development of a small but very powerful spot welder, rated at 25 K. V. A., 20 K. W., which may be either foot or power operated and has a maximum capacity of $\frac{3}{8}$" thickness of steel, or $\frac{1}{8}$" thickness of brass or aluminum.

BUTT WELDING

In the butt welding, the greatest interest during the year has

* Paper read before Boston Section, A. W. S., Oct. 1923.
† Electrical Engineer, Thomson Electric Welding Co.

been shown by the large railroad systems of the country, in welders to safe-end locomotive flues and superheater tubes. A few of the railroads have been repairing their flues and tubes in this way for ten or twelve years, but within the last year, the Grand Trunk, Lehigh Valley, Illinois Central, Duluth & Iron Range, Atchison, Topeka & Santa Fe, the Chicago Junction R. R., the Japanese R. R., and the Manila R. R. have all bought electric welders for safe-ending locomotive flues and tubes. To meet this sudden demand, a new welder has been developed for the welding of tubes, flues and pipes exclusively. It is equipped with air-operated clamps, hydraulic, or oil, or hand pressure pushup, as desired, with an electric regulator to suit various sizes of work from 2" diameter to 5½" diameter.

Another development of the year is an automatic rim welder for the rapid production of automobile rims. The actual welding time is from .6 to .8 second. The foot-controlled, air-operated clamps make it possible to insert and remove the rims in a remarkably short space of time, so that it is possible to weld from 10 to 20 rims per minute. Formerly five rims per minute was the maximum production. Now production can be increased four-fold.

Another development is the practice of installing oversized transformers in Butt Welders to enable them to do bigger and faster work. There are many advantages, and only one disadvantage in this practice. For example, a Butt Welder was recently sold to flash weld ¾" diameter hand cranks for automobiles. The welder was of 15 K. W. capacity and made the welds in an actual welding time of six seconds each. This, however, was not fast enough to meet the production demands of the customer. Accordingly, a 50 K. W. transformer was installed in a welder, which welded the cranks in two seconds. The advantages in this case were increased production, a stronger weld, and a decreased amount of burr or extrusion left on the crank to be removed.

The disadvantage of this and all similar cases is the larger standby charge made by the local power company to cover 50 K. W. instead of 15 K. W. of power installation. But the old law, "You can't get something for nothing," applies to electric welders as well as to all other machinery. To do the same size work in half the time requires twice the kilowatts. The reverse of this statement is also true. Hence, it becoms a matter of production, and local power conditions, whether a large or a small welder should be installed in any given plant.

The tendency, however, is for more rapid production, regardless of standby charges. Perhaps the most interesting welding proposition of the year arose in connection with cylinder heads for Liberty Motors for the Aviation Branch of the War Department. It requires twelve of these heads for each engine. There are sometimes as many as four engines used in a single army plane. There are two intake and two exhaust port lugs on each head. It formerly required from 12 to 14 hours to gas weld or

arc weld these port lugs onto one head only, and there was always trouble from leaks around one or more ports. Finally it was decided to drop forge the head in two halves with two port lugs on each half and try welding them together along the center axis by the butt welding process. The actual area to be welded was 7¼ square inches of drop forged high carbon steel. The heads were welded in from 2 to 2½ minutes each, and after being given an exhaustive laboratory test by the War Department the work was pronounced first class.

You will note the enormous saving in time that would result in case of another war in building aviation motors—nearly 14 hours per head on from 12 to 48 heads for one aeroplane only.

Very little thought or time has been given to the art of seam welding during the year, although there is a wide field for its use. There has, however, been one new and interesting application of a seam welder recently and that was for seam welding the ends of .010″x8″ steel sheets together into one continuous sheet. The sheets are then run through a multiple slitter which cuts them into strips or ribbons ¼″ wide. These ribbons are then woven into very handsome but inexpensive fruit baskets and used for the marketing of strawberries, grapes, etc.

There is a large and varied assortment of samples constantly before us, all the way from raising and salvaging ships sunk during the war, by welding under water—to the welding of keys and letters on typewriter levers and stems on watch cases. It is for the welding engineer to decide and impartially advise whether or not the propositions are feasible. It is needless to state that many of them are not.

FLUXES AND THEIR FUNCTIONS IN ELECTRIC ARC WELDING*

J. CALDWELL †

Character of a Weld

The microscope shows that in a good weld the crystal grains of the separate portions have interlocked either with each other or with grains of a mixture or combination of both. That is, the union across the weld is of the same intimate character as that between the crystal grains of a solid piece of metal. If the separate pieces were of the same description it should not be possible to distinguish any sharp line of transition.

The structural character of a weld is well shown by a section across a weld between two metals which do not alloy, say brass and iron. The microscope shows that brass grains interpenetrate between the iron grains, and iron grains interpenetrate between the brass grains (crystals). They interlock like the portions of a jig-saw puzzle when properly assembled.

* Paper presented before the Nov. 1923 meeting, New York Section, A. W. S.
† Managing Director, Alloy Welding Procces, Ltd.

This definition of a weld by its structure does not limit the methods by which it is produced. The intimate union which it implies may be brought about by fusion, when the contiguous liquid portions intermingle, or by pressure, when the contiguous surfaces are sufficiently plastic to allow of the pressure forcing the surface grains into intimate contact. In practice heating to the fusing point, or to a temperature near that point at which the metal is plastic, is a part of every welding process.

Fluxes in Steel Manufacture

In modern methods of steel manufacture fluxes play an essential part. Roughly it may be said that the steel maker starts with pig-iron, etc., as his raw material, that he treats this crude iron by a fusion process, and while it is melted acts upon it with reagents which have the effect of removing certain constituents and adding others, so that the original crude iron of a certain composition is converted into a steel of a different composition.

Some of the reagents used are of the nature of fluxes. A very simple example occurs in the basic process of making mild steel. The special object of the basic process is the removal of phosphorus from the iron, and the fluxing material used is lime, generally in the lining of the furnace. The phosphorus is oxidized and the resulting phosphoric acid combines with the lime to form (with other things) a fusible slag.

In other processes of steel manufacture fluxes of known composition are allowed to act upon the metal for certain times at certain temperatures, and sometimes two or more different slags are used and removed in succession to bring about the desired changes in the composition of the steel.

The steel maker would be lost if he were deprived of the use of the fluxes and slags as reagents, or the vehicles of reagents in the chemical processes conducted at high temperatures which change the raw material into the finished product of desired composition.

Fluxes and their Functions in Arc Welding

In welding ferrous metals by the metallic arc process the adjacent edges of the pieces which are to be joined are fused by the heat of any electric arc of which they jointly form one pole, and metal is added by projection from the highly-heated end of the other pole of the arc, generally distinguished as the "electrode." This electrode is a wire or rod of ferrous metal. The junction is therefore made up of metal from three sources, two of them the pieces to be joined, the third the electrode. The pieces to be joined may be called the "work."

Both the work and the electrode are raised to a temperature at which oxidation is rapid in the presence of air. The electrode is hotter than the work, and if bare will be oxidized rapidly for some inches above its points. The surfaces of the work and of the metal already fused also oxidize. The oxide is a danger to the soundness of the weld, as it may mix with the fused metal and fail to separate before the metal solidifies, forming an inclusion.

Covering the electrode with some material which shields it from the air until it is on the verge of the arc prevents much of this oxidation and saves electrode metal.

But a flux covering does more than this to prevent oxide inclusions. Following the smith's use of sand, it may have such a composition that it fuses and combines with iron oxide to form a light fluid slag, which floats on the molten weld metal and does not get entangled with it. This fluid slag also protects the hot work and weld metal from the air, and by combining with any oxide present, cleans the work surface and promotes the union of the metal projected from the electrode. It acts in at least three ways:—

1. In its solid form on the electrode it protects the electrode surface.
2. In its fused state it protects the work and weld surface.
3. It picks up whatever oxide is formed and makes with it a light mobile slag.

It may act in yet another way to the same end. The flux covering may be volatilized wholly or in part by the heat of the arc, and form a vapor sheath or jacket around the arc, preventing access of air to the iron passing through the arc.

That a suitable covering does provide such a jacket external to the arc proper has been proved by experiments with alternating current welding, when it is possible to view the arc at different current phases.

So the first important function of a flux covering is to reduce the liability of oxide inclusions in the weld metal, partly by reducing oxidation, partly by confining oxide to the surface, and partly by cleaning the surface of the work in advance of the arrival of the projected electrode metal.

It is important that a weld shall be homogeneous in respect to chemical composition and mechanical properties with the material of the work. For if it is not homogeneous in these respects, the weld will resemble in greater or lesser degree a soldered or brazed joint consisting of a zone of material from the pieces which it unites. It is therefore desirable that the weld metal derived in part from the electrode shall be similar to the work metal.

Experience shows that this desirable similarity cannot be secured by using as the electrode metal of the same composition as the work metal. In passing across the arc the composition is altered. Carbon and silicon, for example, are removed, and as a general rule the metal deposited from an electrode of any ferrous metal is more nearly pure iron. This may be satisfactory for welds in wrought iron or low carbon mild steel, but is not so for, say, cast iron, manganese steel, or any alloy steel in which it is important that either the mechanical strength or the chemical properties of the weld metal shall be substantially equal to those of the work metal. An example is stainless steel; a weld which will rust is unsatisfactory for uniting two pieces of such steel.

It therefore appears that if the weld is to match the work the necessary qualities must be imparted by reactions with the flux material. This is the same kind of problem as the steel maker has solved by the use of fluxes or slags, and it is found by experience that it can be solved by the proper composition of the flux covering of the electrode.

So another function of the flux covering is to provide a slag reagent to impart to the weld the desired composition.

Another function operates in welding with alternating currents if the covering gives off a vapor which remains gaseous at lower temperatures than iron vapor and has some conductivity. A sheath of such vapor maintains a conducting path through which current passes while the voltage is too low to maintain an iron arc. It is certainly the case that with such a covering alternate current welding is much easier and less subject to the breaking of the arc than with a bare electrode.

Flux Covered Electrodes for Arc Welding

The general result of much experience is that for welding iron and steels it is useless to adapt the composition of the metal electrode to that of the work. The only way to be sure of getting a weld metal of any desired composition is to adapt the composition of the covering.

For example, when welding cast-iron the coating carries carbon in such a form and quantity as to combine with the metal in the required manner, with the result that a microscopic examination of a section across a weld shows a structure which is that of a typical cast-iron. Similarly with alloy steels, the desired composition is produced by flux reaction with the deposited metal.

Why certain constituents are lost from the metal and retained in the flux is rather conjectural. Probably it is because the covering material does not pass through the arc but goes across in a zone or jacket which is at a lower temperature.

It should be said that the steel makers' practice and results are by no means directly applicable to the composition of arc-welding fluxes.

The conditions under which the reactions occur are very different.

In the furnace, the atmosphere—reducing or oxidizing as required—and the temperature of the metal, are under control, the time during which the metal and the flux or slag are in contact may be minutes or hours.

In arc welding the metal passes from a temperature much higher than that of any furnace to the temperature of solidification in a few seconds as a maximum. The reactions must therefore be very rapid. The high temperature doubtless favors rapidity, but the reactions may not be similar.

Besides the desired composition of the weld metal a flux covering has to satisfy other requirements, such as, for example, those of a mechanical nature.

The covering must not melt too easily or it will run off the metal, leaving bare metal for some distance from the arc, and will not get to its proper place as slag.

It must not have too high a melting point or it will "cup," project beyond the fusing end of rod and embarrass the operator by deceiving him as to the arc length.

The covering should fuse level with the rim of the crater of the rod. Electrodes for "overhead welding" have to be specially made.

One which works well with the work undermost may behave very badly where the work is above.

Discussion of Paper On Fluxes and Their Functions *

C. J. HOLSLAG †

Electric Arc Welding Electrodes are of two general types, namely, Bare Wire or Flux Coated. Of the bare wire electrodes there are two general types—pure iron and mild steel.

Forgetting for the moment the various types of alloy steel electrodes the pure iron electrode was the original electrode, and up to the World War was the only one universally accepted as being good. The War, however, proved that mild steel electrodes were the equal of the pure iron, and each at the present time is greatly used.

Of covered electrodes there are two general types: heavily covered slagging electrodes and thinly covered fluxing electrodes and combinations of the two. Heavily coated slagging electrodes aim to retain the metal in its purest form by protecting the arc stream and deposited metal by a heavy slag covering.

The flux electrodes aim to protect the metal by chemical reagents which attack the undesirable elements and develop an inert gas around the flame to protect from further oxidation or combination with nitrogen. Combinations of the two contains the fluxing materials mixed in with the slagging envelop, which would appear offhand to be the best arrangement. However, as it requires great skill to properly deposit one of these heavily slagging electrodes and as the method used with these types of electrodes is far different from the ordinary wire or thinly flux-coated electrodes, its use is not so prevalent in this country. There is also a great deal of chipping and brushing necessary, whereas with the flux-covered electrodes no such chipping is necessary.

All slag electrodes are practically 95% silica or silicate, while flux electrodes have very little of this absolutely inert mass and are mostly made up of deoxidizing and quieting reagents, such as calcium or sodium compounds. Electrodes for special use, such as for non-ferrous welding and alloy steels, contain special reagents in the flux to produce the desired fusion.

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* Presented at the Nov. 1923 meeting, New York Section, A. W. S.

† Chief Engineer, Electric Arc Cutting & Welding Co.

Each type of electrode is best for some particular use. There is no shop which cannot advantageously consider the use of all types of electrodes. No matter what type of electrode, the weld is a casting and should be treated as such and no casting can ever equal a rolled member and only disaster can follow the use of a weld that will be expected to equal all the properties of a rolled plate.

Flux-coated electrodes can be used the same as bare electrodes, that is, in any direction or any combination of beading, weaving or padding, but bare electrodes cannot in general be welded vertically downward, although flux-coated can be so welded. Heavily coated or slagging electrodes can only be used in one way successfully, and that is weaving from side to side as advance is made. This is hard to describe, but the main idea is to keep the slag in back of and to one side of the puddle so that it is not included in the weld.

FRAME WELDING*

A. F. DILLON

A locomotive frame, the vital member of the immense piece of power concentrated in our modern locomotive must withstand the shocks and strains which it is continuously subject to while in operation. Imagine the amount of strain put on a frame while a locomotive is moving a train of 100 loaded cars and possibly on an irregular track. With continuous vibration, twisting and hammering that a frame gets it's a wonder that they stand up as well as they do.

In the various mechanical magazines published for the railroad industry I have read many articles on the welding of locomotive frames. Some advocate the use of thermit; some electric arc and some acetylene or oil, but no matter which process is used it is essential that there be a system in the preparation and execution of the weld. Failures in frame welds may be contributed to some of the following facts:

Incompetent welders.
Improper expansion.
Failure to retain the required heat.
Poor welding rods and the releasing of the spreading device too soon.

The hardest job a welding foreman has in preparing a frame for welding is getting the locomotive stripped to make it convenient for a welder. Most of the other foremen in the shops cannot see the necessity in removing the castings, rods, etc., surrounding the break in the frame; but nevertheless it is absolutely impossible to expect a welder to produce his best if he has to work in a cramped, unhandy position. He is the man whom you depend on for a suc-

* Presented at the Oct. 1923 meeting, Chicago Section, A. W. S.

cessful weld, therefore, make it as convenient as possible, so that he will have a free movement of his body and arms.

If it is necessary to remove a cross brace, stiffner or a radius rod, it is cheaper to remove them than make a second weld.

During my experience in welding I have been ordered to weld a frame through the spokes of wheel and the results were what you or I would expect,—a failure. The making an important weld through a knot hole is a poor road to successful welding.

Systemizing your frame jobs means that every man must know what to do and when to do it; the helper must have the oxygen, acetylene, welding rods, flatters, fullers and sledges on the job and see that the outfits are in readiness at all times.

We weld frames of all description, ranging in size from 3x4 to 8x8. The condition existing in every frame weld is not the same. There may be frames of a 4x4 dimension that require more expansion than some other frame of the same dimension, due to its location or relation to some section of the locomotive where more strength is required at one point than at another. When a frame is hard to expand because of its location or it being closely coupled at the point of fracture, it is very necessary that the expansion be increased a small amount to take care of the contraction which takes place more rapidly when the spreading device is taken out.

The following table is used in spreading. The figures are approximate and based on our experience:

3x4	Sections	1/4
4x4	"	5/16
4x4½	"	11/32
4x5	"	3/8
5x6	"	13/32
6x8	"	7/16
6x9	"	½
8x8	"	½

The most convenient method in spreading a frame is with the use of a frame spreader. This pattern of spreader can be used in most any part of the frame and when once in position it is an easy matter to get the spread and hold it on ordinary frames.

Our method is to cut a slot in the frame at the point of the fracture to enable the use of a wedge, then by alternating the sledging first on the wedge in the frame, then in the wedge in the spreader it is not hard to get the required expansion. In cases where it may be hard to hold the expansion the use of two spreaders will eliminate troubles.

The use of jacks are not so sure a way to hold the expansion, where in cases it is necessary to keep the jacks in the frame for several hours. Our experience has been that with th strain placed on the jacks they will give a little during the time the frame is spread until it is welded.

The next procedure in the preparation of the frame is to cut the two sides to a double vee, after which it is chipped. A piece of ⅜ spring steel is then tacked at the bottom of the frame to serve as a foundation to start the weld. One of the main items in frame welding is that of holding a welding heat during the entire welding operation. This very problem has been the cause of many failures. The use of 1½" lagging, tightly wired to the frame, will hold more heat than any other method I know of. The heat generated by the welding torches which are kept on the frame from the start to the finish, will not radiate through the frame for any great distance, and the immediate section around the weld will be kept to a welding heat until the weld is completed. The use of three or four welding torches, as the case may require, will heat up the frame quicker than any other method. At the time the heat is obtained the welder is ready to continue instead of having to tear down a furnace as is generally the case.

Our usual procedure in welding is to lay a heavy ripple weld up one side, across the front, up the other side, etc., always keeping the back center of the weld higher than the front, continuing this method until the frame is completed.

In cases when the frame is larger than a 4x4, a piece of lagging is placed over the added metal and on the bottom of the weld, thus keeping the bottom of the weld practically as hot as the top. After the weld is completed it is trimmed on both sides and with the use of flatters, fullers and a sledge the frame is dressed up to most any shape necessary. The spring steel can be easily removed from the bottom and after the bottom is trimmed up the lagging is again applied and the frame allowed to cool slowly.

In releasing the frame spreader there are many things to consider. In cases where it was hard to get the expansion the logical thing to do is to hold the spreader until the trimming is completed. Where the expansion is fairly easy to get, the spreader can be taken out when the weld is three-fourths finished. Following this principal we generally get a frame to come back to the original tram marks. In case a frame comes 1/32 to 1/16 long it is advantageous as you have a compression instead of a tension weld.

Our system is to take all the time necessary in making a weld and follow the idea of letting the metal settle in as quiet a condition as possible, instead of allowing the added metal to run all over the weld; whereby one is apt to get laps, checks and seams which in most cases hard to get out.

We use from 3 to 4 welders on all frames, the larger frames require 4 men, so that no one gets to a point where he becomes so tired out toward the finish of the weld that he starts piling in the metal to get the job completed. The welders are alternated at regular intervals, and they are not left on the job too long.

One example of frame welds which are required to withstand an enormous tonnage pull is one made on one of our H-10 type of freight Loco. where the frame broke close to the rear deck casting

requiring 4 welds, one on each rail and the full pull of the draw bar comes directly on the 4 welds.

Another example is that of placing new front sections on our E7s which are heavy sections welded to the rear end at a point just ahead of the fire box.

COST OF FRAME WELDING

	Labor	*Gas*	*Oxygen*	*Rods*	*Total*
4x4	$11.72	$7.35	$4.20	$5.00	$28.27
4x5	13.18	8.92	5.00	5.00	22.10
5x6	14.70	14.70	8.40	5.25	43.05
6x8	26.18	21.00	12.00	6.00	65.18
4x9	26.18	15.75	9.00	5.75	56.68

SOME MANAGEMENT PROBLEMS ON PIPE WELDING JOBS *

G. O. CARTER †

Half a dozen years ago we would probably have meant the repair of a large casting or the welding of a locomotive fire box when we said "A large welding job." To-day single repair jobs may still be classed as "large jobs," but welding is extending so rapidly that single jobs may require many weeks' work of a crew of ten or twenty men or even more.

As all who have been responsible for organizing welding crews know, it is necessary to thoroughly check the ability of each welder for the kind of work being undertaken. Advertisements for welders will bring a dozen applicants for each man who will qualify as a welder—so it was not easy to get the first crew together for some welding jobs, such as, for example, pipe welding. The test found most satisfactory for checking welders on pipe welding of oil lines is the bending test. Each candidate made sample welds of short pieces of pipe which were cut into strips and examined for penetration and to make sure that the welder did not make icicles. Then the pieces were put into a vise and bent until fracture occurred. With this test it is easy to make sure a welder is getting fusion instead of adhesion and that the deposited metal is in good condition.

Having enough welders in sight the next problem was organizing a gang of both welders and laborers. As many good welders can make satisfactory welds when the work is in a horizontal plane yet can not do good work on a vertical or overhead seam; and as it is cheaper to weld when the work is horizontal, it was decided to weld as many joints as possible with the pipe above ground and have them turned so the welders could work directly downward. This meant having the pipe placed end to end on saw horses or rollers and having a couple of laborers to turn the pipe.

* Paper read before the Nov. 1923 meeting, Northern New York Section, A. W. S.
† Consulting Engineer, Linde Air Products Co.

The length of such sections was naturally controlled to some extent by the character of the country and a section of five or six joints was found to be most suitable.

Fig. 1—Making a "Bell-hole" weld in welded oil pipe line.

Fig. 2—Section of 8" pipe being snaked into trench.

It is apparent that it will be easier to weld around a pipe if it is above ground instead of being in the ditch, although it is sometimes necessary to make what is called a "bellhole weld." The Prairie Company first tried out welding on a single section of about fifteen miles, then as not one of the anticipated troubles

developed another section of fifteen miles was welded. Thirty-five miles of line were relaid, using welding wherever possible.

The primary anticipated trouble was that welders would penetrate into the pipe with the deposited metal in which case the scraper, which is sent through an oil pipe line, would catch and necessitate the digging up of the line. A very simple trick was developed which seems to entirely overcome the difficulty from excess penetration. The torch is held so that the flame is parallel to the plane of welding instead of being perpendicular thereto and

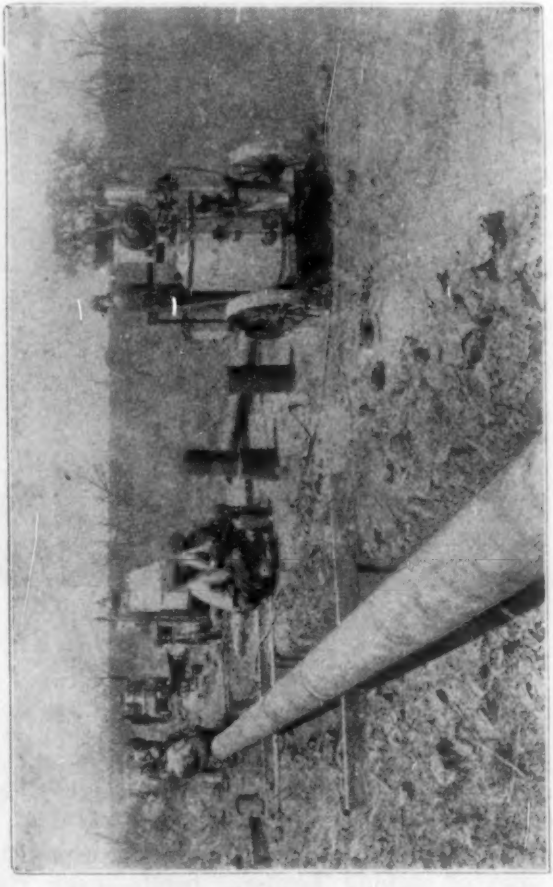

Fig. 3—Welding Section of gas line on skids over trench.

the pressure of the issuing gases is entirely away from the point where it would make the molten metal flow through the unwelded part of the joint and into the pipe itself. This developing of a unique method to suit conditions may be classed as engineering, but it is also a necessary part of management to see to it that methods are found to overcome sources of potential troubles.

To check up with each man's work it was found desirable to have each welder stamp a mark near the weld. There are other

points which might well be mentioned, but you probably all know of the success of the welded oil pipe line of the Prairie Company and several other companies which have recently gone into welding of pipe lines extensively. Besides the welding of oil lines there is a great deal of welding of natural gas, manufactured gas, steam, air and hydraulic lines.

The welding of natural gas lines usually follows the general principles of oil line welding as the work is done across country, but with manufactured gas the lines are usually laid in large cities

Fig. 4—Welding 16 inch oil line in Texas.

with occasional high pressure lines between cities. The management problems with regard to welding pipe line for city distribution have mostly been with regard to selection of good men and compensation. The use of welding has so simplified pipe line problems that where it has been tried it has quickly become standard for joining wrought iron and steel pipe.

The welding of steam pipe is more of a shop proposition, a good part of the work of making headers, bends—even eighty to a hundred-foot sections over all being done there. The only field welding is the making of the tie-in joints. The welding of seven or eight miles of steam pipe of from six to sixteen inches constitutes a recent job and there are enough problems to keep a manager pretty busy. Sometimes industrial plant jobs must be done on a cost plus basis and one very good method for so doing is to arrive at a unit cost per joint for each size pipe and for each character of weld; i. e., end weld, right angle, neck weld, etc., and a

rate per lineal foot for any longitudinal welding. Using such unit costs there is no argument at the end of the contract.

Outside of the pipe welding field there are several industries where welding is a major part of the total construction. The welding of gasolene storage tanks, tank wagon tanks, oil and paint barrels, ammonia receivers, range boilers, light gauge tubing, etc., are

Fig. 5—Bell-hole Welding—"Tying-in" section of welded line.

all of great industrial importance, so may be classed as "large jobs." In most of this work there is a great deal of sales competitiontion, so a manager is "hard put" to so organize as to make a profit. This requires a study of production methods, having the materials move from operation to operation with a minimum of lost motion, having the material correctly prepared, buying the right grade of materials, then developing such methods as "jigging" to assure having sizes of finished work correct and to reduce labor charges to a minimum. Satisfactory test methods are also an important part of the problem.

A field which is just opening up in the welding of large tanks such as oil storage tanks, gas holders, etc., will certainly require careful management. Bad results from welding the first tanks will set back the welding of tanks just as poor workmanship on a

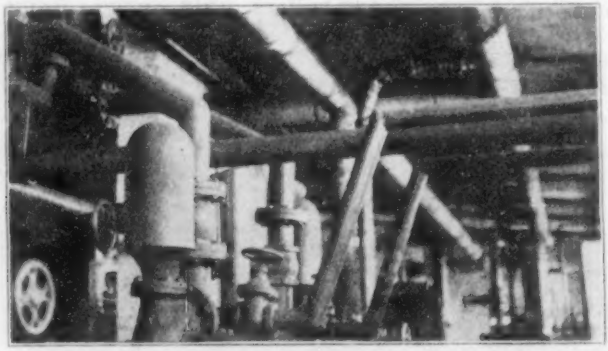

Fig. 6—Welded pipe in power plant.

gas pipe line ten years ago is still occasionally referred to. Only the results are unfortunately not credited to poor workmanship but to the process. We are therefore all of us vitally interested in the management of all the big welding jobs. And although there is at least two major welding processes entering into the realm of "large jobs" we must none of us forget that successes or failures are credited to "welding" as little distinction is drawn between the two processes by the average citizen or even engineer.

Fig. 7—Welded heating coils.

Correct welding principles have been established for welding under varying conditions for each of the major processes, so we should all of us keep them in mind when we come into contact with the managers of large jobs. Setting the manager to follow the best welding principles will be one of the most important things we can do for some time to come. If we could get the managers to take an active interest in the Welding Society the industry would be very much better off.

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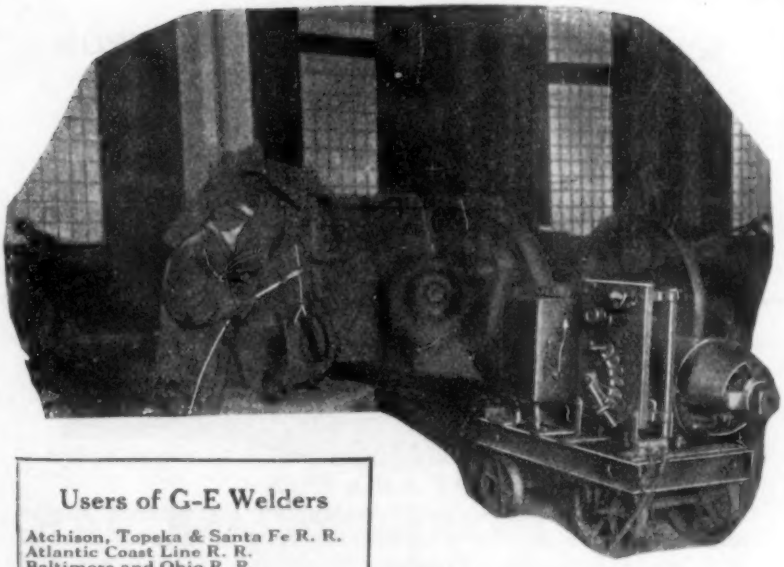

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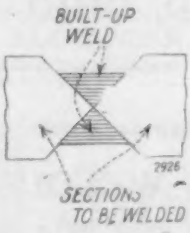

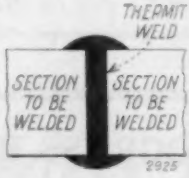

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